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Age Changes in Shape and Morphology in Arikara Subadult Ilia

David R. Hunt

To the Graduate Council:

I am submitting herewith a thesis written by David R. Hunt entitled "Age Changes in Shape and Morphology in Arikara Subadult Ilia." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of , with a major in Anthropology.

Richard L Jantz, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

William M. Bass

B Willey

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

AGE CHANGES IN SHAPE AND MORPHOLOGY IN ARIKARA SUBADULT ILIA

A Thesis

Presented for the

Masters of Arts

Degree

The University of Tennessee

David R. Hunt

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ABSTRACT

This study examines the growth of the ilium in an American Indian skeletal series. This study was done because of the lack of previous study in this area using statistical interpretation of the changes. The samples consists of subadults from four Arikara cemeteries found in northern South Dakota; two of the samples are separate occupations of the same site. An unknown age and sex sample was used because of its availability and because of the unavailability of known subadult skeletal samples.

Eight measurements were taken on each ilium and two non-metric traits recorded. Maximum femur lengths, gathered in a previous study, were then matched with their corresponding ilia. Femur length was used as an indication of biological age and used to hold age changes constant. Logrithmic transformation of the raw data was performed to eliminate non-linear trends in the femur length to iliac relationships.

Allometric regression coefficients were calculated indicating relative rates of growth for each of the eight variables. Regression and eigenvalues were generated and principal components calculated for the eight variables. Inter-site correlations were evaluated from the residual means of the principal components. Each site was found to be significantly different from the other in growth rates. Principal component analysis is examined and no significant components found.

Two non-metric traits were examined, the raised or non-raised shape of the auricular surface and the presence or absence of a spinous process on the posterior aspect of the sciatic notch. It was thought in a previous study that the auricular surface trait indicated sex differences in subadults. Results from this study show no significant sexual differences in either non-metric trait but only an age relationship associated with the age of ilium. One point of interest is the significant correlation of the two non-metric traits, the non-raised trait associated with a spinous observation and visa versa.

From this study it is concluded that there are apparent but no significant correlations in the morphological changes due to age. No sexual separation was found in either the metric or non-metric data although correlation between the two non-metric traits was discovered. The causes for non-significant results is discussed and possible corrections proposed. Even with only trends and no significant results, the findings in this study shed some light on the age changes found in subadult ilia.

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I. INTRODUCTION

Opening Remarks

Growth and development has been the subject of numerous investigations in human populations and non-human primate species. In these studies, the main concerns are the changes which take place during the growth period of the species resulting in the adult form and its variations. In this particular area of interest, describing and interpreting the interaction of body functions during their growth becomes a difficult and sometimes almost impossible task. Because of this, most studies have dealt with only a fraction of change in one specific area, disregarding other effects. But increasingly these studies have incorporated statistical analysis performed by computer programs allowing much more intricate evaluations to be performed. This change has been brought about by the relatively recent availability of sophisticated computer systems for general use by scholars. A good deal of study has been performed on the human body using these relatively new analytical procedures, but there still remains portions of the anatomy which have not yet been scrutinized. One of these lesser studied areas will be the focus of this particular paper, the subadult human ilium.

Survey of the Literature

As of yet, no investigations have primarily studied the growth and development of the subadult ilia either by morphological or statistical means. In 1972 Sundick did a skeletal growth study of the Indian Knoll population for his Ph.D. dissertation which included the breadth of the ilium from anterior to posterior iliac spine. Merchant and Ubelaker (1977) used Sundick's same measurement methods to evaluate different dental aging methods. They evaluated the discrepancies in the growth curves of their Arikara sample to Sundick's sample and the differences of the Moorrees, Fanning and Hunt (1963a, 1963b) and Schour and Massler (1940, 1944) dental aging techniques. No discussion of the growth curves meaning were done. Each of the known studies on subadult ilia is interested in possible ways to determine sex in the individual with developmental changes being only secondary.

Other studies have been interested in sex differentiation in the pelvis. The earliest of these was by Thomson (1899) using prepared pelves dissected from fetuses. The bones were measured and overall morphology was recorded with the pelvis and cartilage intact. Means of measurements were made and sexes compared with observed differences. The sample size is never discussed but seems to be quite small so any trends are questionable.

Reynolds (1945, 1947) made similar studies of the complete pelvis of early infancy (1945) and prepuberal (1947) using radiographic techniques. A series of roentgenograms were made of American White male and female fetuses at birth and one, three, six, nine and twelve months and measurements were taken on the films and indices calculated. The conclusions for the infant pelves were that males grew faster in height, breadth and in bi-iliac breadth while females grew the most in bi-ischial breadth, pubis length and sciatic notch width. The prepuberal sample followed the same procedures with films taken at fifteen months to nine and one half years. The conclusions of this study were in agreement with the infant study. Both Thomson's and Reynold's studies concluded that males have larger exterior pelvic structures while females have larger interior structural growth. While these two studies help with understanding the changes between males and females in fetal and subadult growth, it is impossible to correlate the measurements and indices to bony skeletons devoid of cartilage and tendons.

Boucher (1955, 1957) also studied dissected articulated infant pelves, taking measurements to derive indices. However, she made measurements of the sciatic notch widths and depths after macerating the bones from the cartilage. This was the first study of the bone itself for sex differences. Boucher (1955) found significant sex differences in the sample of British White fetuses and was able to determine sex with a fairly high degree of accuracy (Table I). In the 1957 study, American White and Black fetuses were analyzed and her method was found to work reasonably well on the American Blacks, but the American White sample did not separate with any significant results (Table I).

Weaver (1980) studied ilia from the Hrdlicka collection of fetal skeletons at the Smithsonian Institution. Each individual had a known sex and age. Overall ilium measurements were taken along with measurements of the sciatic notch of 154 individuals (Fig. I). A non-metric trait was also introduced into the analysis. This was the raised or non-raised appearance of the auricular surface which is considered a sex discriminating trait in adults (Bass 1979:159; Stewart 1979:108; Ubelaker 1978:42). Weaver found that there were no

Table I. Data on the Sciatic Notch Index in Macerated Fetuses and "Stillbirths" of Known Sex for Use in Skeletal Sexing

Racial group	No.	Mean ± S.E.	Range	Percent correct
Whites		*Males*		
Great Britain	46	4.57 ± 0.091	3.65 — 6.0	80.43†
United States	19	4.81 ± 0.436	3.9 — 6.0	57.8 †
Blacks				
United States	49	4.84 ± 0.0085	3.38 — 6.8	73.3 ‡
Whites		*Females*		
Great Britain	61	5.64 ± 0.096	4.0 — 7.3	88.52†
United States	14	5.41 ± 0.23	4.9 — 6.68	71.4 †
Blacks				
United States	47	5.81 ± 0.021	4.35 — 8.77	95.1 ‡

•From Boucher, Sex differences in the foetal pelvis. *Am J Phys Anthropol, 15:* 581-600, Table I and p. 589, 1957. Courtesy of *Am J Phys Anthropol.*
†4.9 and below = male, 5.0 and above = female.
‡5.0 and below = male, 5.1 and above = female.

Source: B. J. Boucher. (1957) Sex differences in the foetal pelvis. American Journal of Physical Anthropology 15:589, Table I.

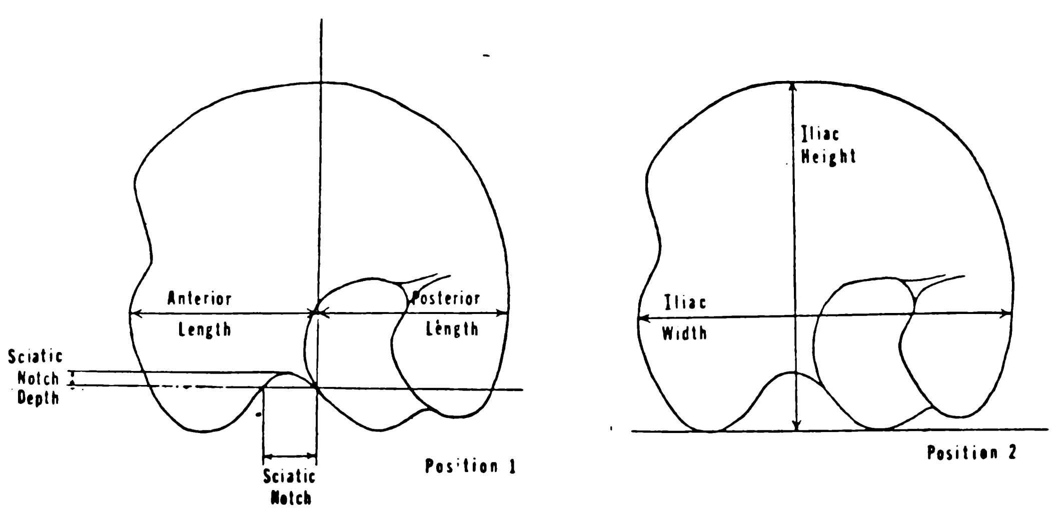

Figure I. Ilium Measurement Positions Used by Weaver

Source: D. S. Weaver. (1980) Sex differences in the ilia of a known sex and age sample of fetal and infant skeletons. American Journal of Physical Anthropology 52:192, 193, Figs. 1 and 2.

significant differences in the metrical data although the greatest divergence between males and females appeared in the chilotic index (Table II). This index involves the position of the auricular surface on the ilium, a feature which was discussed by Thomson (1899:366-367).

The most significant result of Weaver's study was the highly reliable sexing of males by the non-metric trait (Table III). The sample size was somewhat small but still large enough to yield statistically significant results. The females in the sample did not separate as well because, as Weaver (1980:194) explains, "it was required that the auricular surface be elevated along the _entire_ length of both the anterior and posterior edges, if the surface were to be scored elevated. Complete elevation of this sort is not very common even in adult females." He concludes that with further study using larger sample sizes, this non-metric trait and the metric indices may be more fully interpreted.

Growth relationships of the ilia's different parts in the above studies were all attributed to sex differences based on conclusions from adult innominates (Bass 1979:156-162; Hrdlicka 1939:132-133; Krogman 1978:122-142; Phenice 1969; Stewart 1979:104-116; Washburn 1948). But to attempt to derive growth and development data from these studies would result in headaches, guesswork and little valuable information.

The Problem

With the apparent void in analysis of growth and development of the human pelvis it seems appropriate that a study should be made. All previous studies concerned with subadult pelves relied upon indices to

Table II. Three Indices and Data of Fetal and Infant Ilia

		Sciatic apertural: $\frac{\text{Sciatic depth}}{\text{Sciatic width}} \times 100$		Chilotic: $\frac{\text{Ilium posterior length}}{\text{Ilium anterior length}} \times 100$		Iliac breadth: $\frac{\text{Iliac width}}{\text{Iliac height}} \times 100$	
Age groups	n	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Fetal (6–8 fetal months)							
Females	(24)	31.20	6.14	55.65	9.42	116.4	5.46
Males	(24)	32.94	9.54	60.03	13.14	116.5	6.60
Newborn (Birth to 1 month)							
Females	(24)	31.63	7.88	50.47	12.17	116.8	4.26
Males	(26)	31.32	5.49	55.49	11.40	117.0	4.46
Six months (3–6 months postpartum)							
Females	(23)	32.72	6.82	48.98	10.96	114.7	3.27[1]
Males	(32)	32.20	5.73	53.43	8.80	117.7	4.67

[1] $0.005 < P < 0.01$, $t_{(53)} = 2.647$ for a one-tailed test

Source: D. S. Weaver. (1980) Sex differences in the ilia of a known sex and age sample of fetal and infant skeletons. American Journal of Physical Anthropology 52:195, Table 2.

Table III. Auricular Surface Elevation Data

	n	Elevated	Nonelevated	Percent correct
Fetal[1]				
Females	(24)	18	6	75.0
Males	(24)	2	22	91.7
Newborn[2]				
Females	(24)	13	11	54.2
Males	(24)	7	19	73.1
Six months[3]				
Females	(23)	10	13	43.5
Males	(32)	3	29	90.6

[1] $P < 0.005$ $\chi^2_{(1)} = 19.29$, Yate's correction applied.
[2] $0.05 < P < 0.1$ $\chi^2_{(1)} = 2.81$, Yate's correction applied.
[3] $0.005 < P < 0.01$ $\chi^2_{(1)} = 6.84$, Yate's correction applied.

Source: D. S. Weaver. (1980) Sex differences in the ilia of a known sex and age sample of fetal and infant skeletons. American Journal of Physical Anthropology 52:194, Table 1.

interpret changes in the metrical data but no statistical methods have yet been used to correlate the changes. This lack of statistical analysis may stem from the need for a large sample size to derive reliable results. Large collections of fetal and subadult specimens of known age, race and sex are few and not readily accessible for study. The low number of subadult skeletal collections and their slow rate of accumulation is due to the unwillingness of parents to give their deceased child to science because of strong parental ties. The deficiency of early childhood and adolescent children will always be a problem since demographically that age period has a lower mortality, but in the last decade or so the social pressures against abortion have been relaxed and the number of fetal collections has increased greatly.

In attempts to find alternative methods to study subadult growth, it seems plausable that by collecting a large sample of unknown individuals from a population, the same changes in morphology and any bimodal separations by sex (if they exist) would appear as in a known sample. The major drawback to this method is the inability to check the results. But by including long bone lengths, approximate biological ages can be attributed to individuals (Bass 1979:170-173; Johnston 1962; Owsley and Jantz 1983; Ubelaker 1978:46-52) and if reliable, sex could be derived by using the methods described above.

By using this indirect method of analysis, this study will use a sample of subadult ilia from an American Indian skeletal population and statistically analyze the growth changes which are present in that bone. Within the study, possible sex differences and site differences will also be investigated. This study by no means will be able to separate or fully analyze all growth factors found in the ilia or differences in the aspects of human variation, but whatever does emerge will shed some light on a little known area.

II. MATERIALS

Three Arikara sites were chosen from the skeletal collections housed at the Department of Anthropology, University of Tennessee, Knoxville. These populations were chosen because of their close proximity to one another geographically (Fig. II), their excellent state of preservation and professional excavation, and also because of their large sample sizes which were necessary for this statistical study. Two other Arikara sites also contained in these collections, Rygh (39CA4) and Sully (39SL4) were not used because of the less optimum preservation states and because of split storage between the University of Tennessee and the Smithsonian Institution in Washington, D.C. The Mobridge site is also in split storage but the sample size contained at the university is adequate enough for this study.

The information below of the three Arikara sites was obtained from Jantz (1972:21-25) or through personal communication.

Leavenworth Site (39CO9)

The Leavenworth site is located on the west bank of the Missouri River about three and one half miles north of Mobridge, South Dakota. It consists of two villages divided by a small stream with most of the cemetery situated north of the eastern village. The site was known to have been occupied from 1803 to 1832 (Wedel 1955:80-1). Excavations of the site began in the early part of this century by Over (1915-1917), M. J. Stirling in 1923 and by the University of Nebraska (Krause 1969). The University of Kansas, under the direction of Dr. William M. Bass,

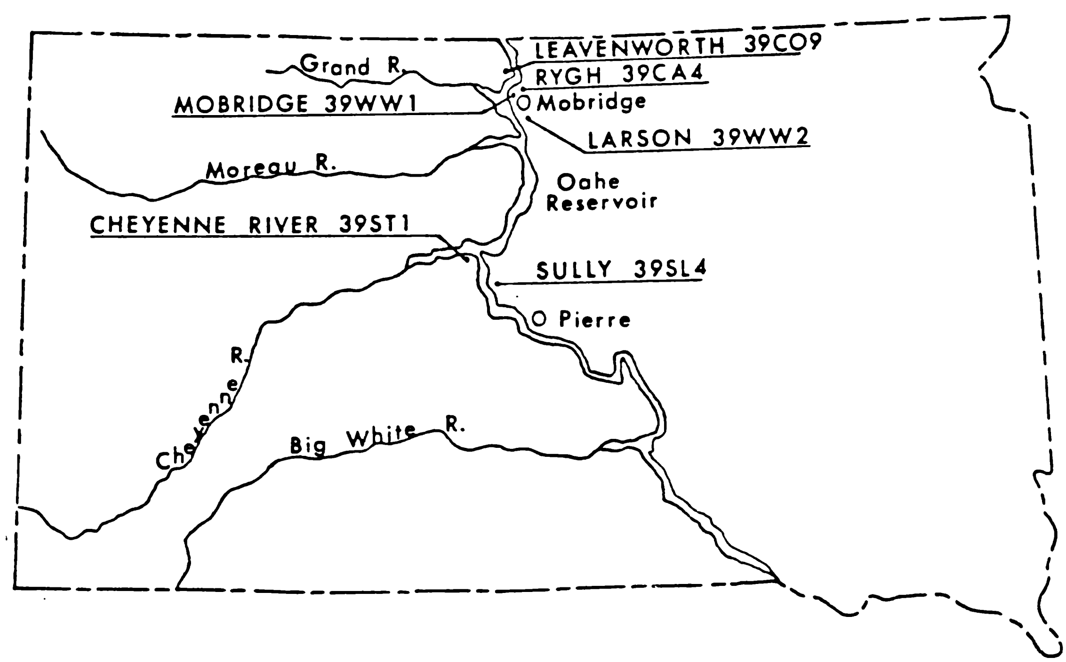

Figure II. Map of South Dakota, Showing the Location of Sites from which Skeletal Material was Obtained for Study

Source: R. L. Jantz. (1972) Cranial variation and microevolution in Arikara skeletal populations. Plains Anthropologist 17:21, Fig. 1.

excavated the cemetery during the summers of 1965 and 1966, uncovering a total of 285 burials. Analysis of this material has since been published by Bass, Evans and Jantz (1971).

Mobridge Site (39WW1)

The Mobridge site is situated on the east bank of the Missouri River less than one mile north of Mobridge, South Dakota. Stirling excavated this site during the same period as Leavenwoth and recovered 40 individuals. Excavation by the University of Kansas proceeded under the direction of Dr. William M. Bass in the summers of 1968, 1969 and 1970. Analysis of the artifacts by Wedel (1955) and from discussions with Dr. R. L. Jantz suggest that there are two different occupation periods at the Mobridge site as indicated by varying percentages of European contact artifacts found in the two discrete cemeteries which were thought to be continuous before. These discrepancies in the archaeological record suggest a period of abandonment between successive occupations of the same site. Even with the hiatus, both occupations of this site were in the latter half of the 17th century (Jantz 1973:23; Wedel 1955:174-175).

Larson Site (39WW2)

The Larson site is on the east bank of the Missouri River about one mile south of Mobridge, South Dakota. The cemetery is east of the village and although no historic evidence proves that this is an Arikara site, the burial style is that of the Arikara. Dr. William M. Bass, while at the University of Kansas, excavated the cemetery during the summers of 1966, 1967, and 1968. Those excavations uncovered 700 burials. The Larson site is believed to have been occupied from about 1690-1730 (Johnson, personal communication).

These three sites comprise the northern extensions of the Arikara from their earlier occupations of the Central Plains and Middle Missouri basin (Jantz 1977:164). The movements of the Arikara peoples have been supported by archaeological and biological investigations (Lehmer and Jones 1968; Jantz 1977). Interaction with Mandan groups during their movements has also been suggested by biological study (Jantz 1973). Ethnographically they lived in fortified earth lodge villages grouped into hierarchial clans which were easily regrouped. Burials were made commonly by flexed, flesh inhumation in small circular pits including artifacts (Lehmer and Jones 1968; Jantz 1977). Ubelaker and Willey (1978) have found indications of occasional secondary burials possibly associated with scaffold defleshing.

With the advent of the White man into the Missouri River basin in the 18th and 19th centuries also came the many epidemics which were to greatly effect the Arikara populations. The best known of these epidemics was the smallpox epidemics in 1780-81 which may have destroyed the Larson population, 1801-02 and 1837-38 and brought the Arikara populations to near collapse (Lehmer 1971:172).

III. METHODS

Data Collection

Complete or nearly complete ilia from individuals before the age of fusion of the tripartate acetabular junction (usually before the age of 11 or 12, Bass 1979:148) were chosen for analysis. The left ilium was preferred but when absent the right ilium was used. Eight metric variables and two non-metric traits were recorded for each ilium. The measurements were designed to describe the shape of the ilium exterior and also contain more specific information about the auricular surface, sciatic notch and iliac crest curvature.

Recording procedures went as follows:

Each ilium was placed upon an orientation device consisting of a plastic base plate with a millimeter grid attached and two vertical adjoining plastic sides. The most anterior edge of the ilium (usually the acetabular epiphysis) was placed upon the vertical edge while the inferior edges of the ilium were situated to the horizontal edge (consisting of the inferior portion of the acetabular epiphysis and the inferior posterior iliac region) (Fig. III).

Five measurements were taken from this position (Fig. IV):

a) <u>Maximum Iliac Length</u> -- taken from the vertical edge to the most posterior point of the ilium perpendicular to the vertical axis. (ILN). After Weaver (1980).

b) <u>Maximum Iliac Height</u> -- taken from the horizontal edge to the most superior point on the iliac crest perpendicular to the horizontal axis. (IHT). After Weaver (1980).

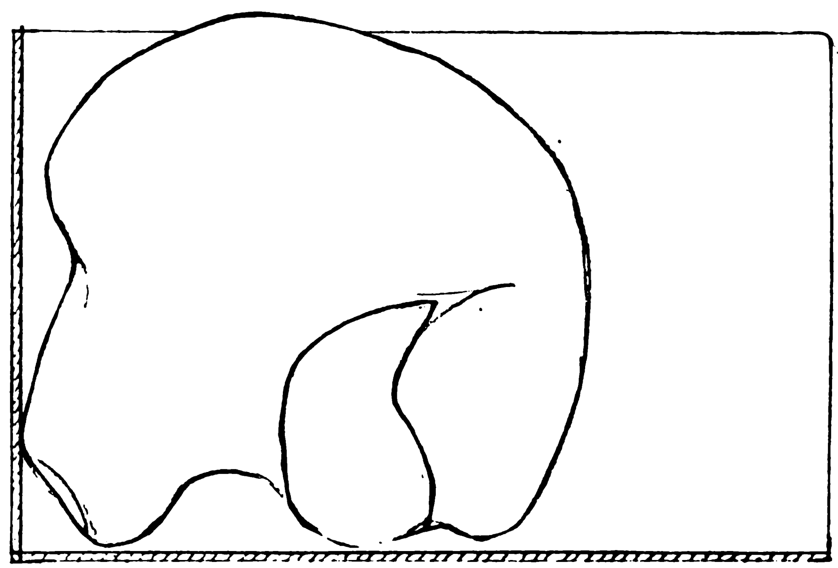

Figure III. Method of Positioning Ilium on Measurement Board

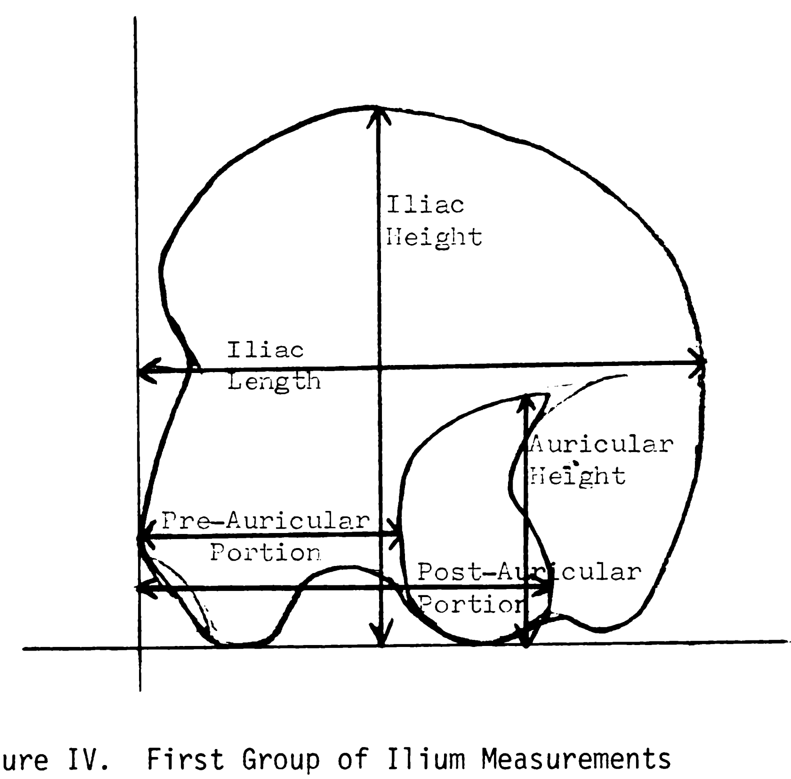

Figure IV. First Group of Ilium Measurements

c) Pre-Auricular Portion -- taken from the vertical edge to the most anterior point of the auricular surface perpendicular to the vertical axis. (PRA)

d) Post-Auricular Portion -- taken from the vertical edge to the most posterior point of the auricular surface perpendicular to the vertical axis. (POA)

e) Auricular Height -- taken from the horizontal edge to the most superior point of the auricular surface perpendicular to the horizontal axis. (AHT)

The ilium was then repositioned on the millimeter grid and the contraflexure points of the sciatic notch were determined following Boucher (1957:585) (Figs. V, VI). The two points were positioned upon one millimeter line and the following measurements taken:

f) Sciatic Notch Width -- the distance between the two points considered to be the contraflexure of the sciatic notch curves. (SWT)

g) Sciatic Notch Depth -- from the line produced by the two points of contraflexure used in the previous measurement, the perpendicular distance from that line to the edge of the edge of the sciatic notch. (SDT)

The ilium was then repositioned along one vertical edge of the orientation device and the last measurement was taken as follows:

h) Iliac Crest Curvature -- the maximum distance between the interior edge of the iliac crest to the vertical edge resting upon the anterior superior iliac spine and the region superior to the auricular surface. (ILC)

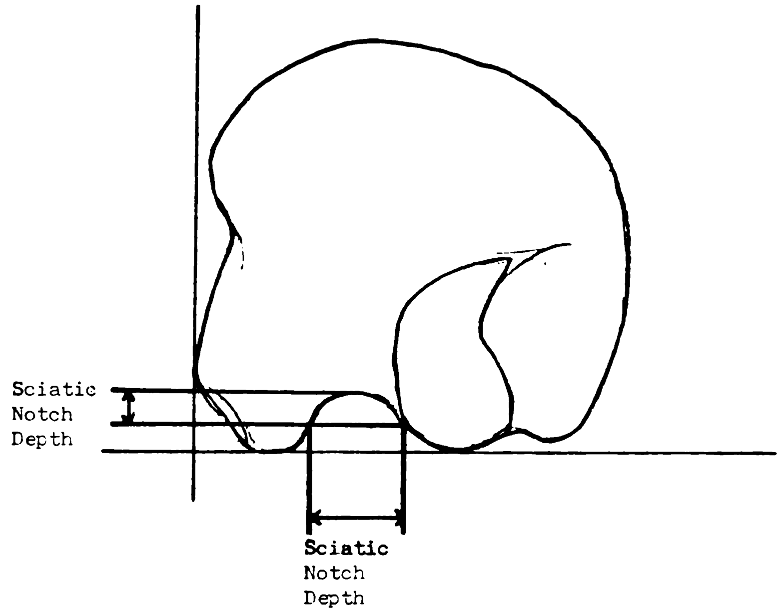

Figure V. Sciatic Notch Measurements

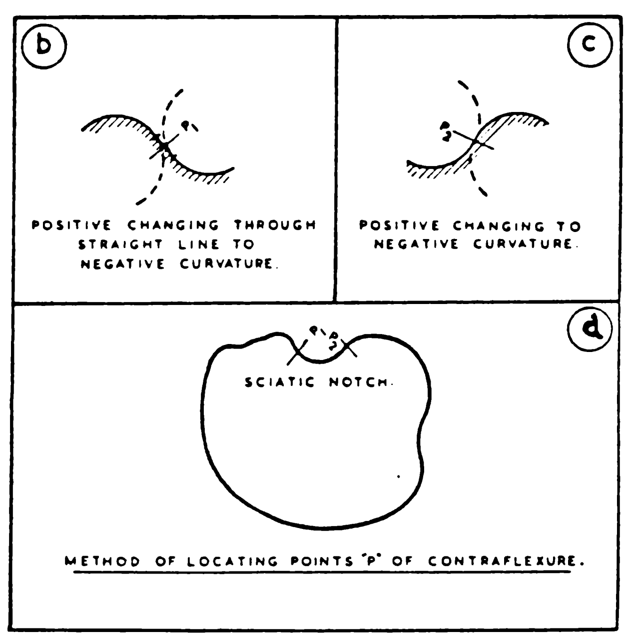

Figure 2

(a) Outline of the ventral surface of a bony ilium to show the sites of the points of contraflexure p. 1 and p. 2.

(b) Diagram to show how p. 1. of diagram (a) was located.

(c) Diagram to show how p. 2. of diagram (a) was located.

Figure VI. Method of Locating Points of Contraflexure

Source: B. J. Boucher. (1957) Sex differences in the foetal pelvis. American Journal of Physical Anthropology 15:585, Fig. 2.

Two non-metric traits were then scored for the ilium inspected as follows:

i) <u>Elevation of Auricular Surface</u> -- following Weaver (1980), if the auricular surface was raised along the posterior edge of the sacro-iliac articulation and the anterior portion of the surface appeared raised or flush to the anterior edge, the auricular surface was categorized as raised. If the auricular surface was not raised along the posterior auricular surface and the anterior portion of surface was depressed, the auricular surface was categorized as non-raised. (APO)

j) <u>Pre-Auricular Spine</u> -- if the ilium contained a small protrusion of ossified bone found directly inferior and slightly anterior to the pre-auricular surface region, the spine was recorded as present. If no spinous process was present, it was recorded as absent. (ASP)

Maximum diaphyseal femur lengths associated with each ilium were then matched using femur measurements previously collected by Dr. D. W. Owsley. The measurement is the maximum length excluding epiphyses since cartilaginous space cannot be estimated. The left side was preferred but when absent the right side was used. The femur lengths were used as a controlling agent in statistically regressing out variation due to growth by holding age constant. By doing this, size is controlled and variation should be due to shape differences between individuals.

Statistical Methods

Statistical descriptive analysis was accomplished by the use of SAS package in the computer system at the University of Tennessee. CORR, MATRIX, PLOT and GLM procedures were all used as part of the analysis (Freund and Littell 1981; SAS User's Guide 1982).

The femur lengths were merged with each corresponding ilium to result in one new data set. Plots were made to evaluate the linearity of femur length to each of the variables. Outlying measurements in these graphs were evaluated and corrected if needed. Not all the variables showed strong linearity to femur length and they produced hyperbolic curves on the graphs. This non-linear relationship requires special curvalinear regression procedures which are tedious and complicated to evaluate. By using the logrithmic transformation technique however, curvalinear correlations can be changed into linear relationships by computing logrithmic values from the raw data. In this technique what is first seen as the classic growth curve is transformed into a linear grouping of the data (Buschang 1982; Simpson, Roe and Lewontin 1960:399-419; Thomas 1976:426-430). So logrithmic values were derived from the raw data and new graphs generated. The logrithmic graphs indicated the linear relationships, allowing regression and correlation to be performed with some degree of precision.

Regression equations were derived for each of the eight variables for the correlation coefficient matrix and eigenvalues and eigenvectors were then generated to calculate principal component scores for each of the variables. The principal component scores were then divided between the four sites Larson, Leavenworth, and the two occupations of the

Mobridge site to generate any significant differences between them. The components were also divided into the bimodal scores of each of the two non-metric traits for evaluation.

Principle component analysis was chosen for this study to help separate the interrelated metric variables. In principal component analysis the data from the variables is converted into a data matrix of eigenvalues through regression and correlation to produce a set of orthogonal (or unrelated) components. These components are fractions of the total correlation formed between all the variables. The first principal component usually contains the greatest amount of information dealing with the most apparent differences. Then the next component is derived orthogonally separate from the first component, usually containing less relevant information, and so goes the process as many times as are variables. The result of this analysis produces a sequence of sets containing the most closely correlated factors in descending order of importance.

IV. RESULTS

Allometric Regression Coefficients

The first analysis evaluated the data using a logrithmic adjusted covariance table to assess ilium to femur length growth rates. This evaluation was supplied by the correlation coefficients calculated from the covariance matrix (Table IV).

Table IV. Logrithmic Regression Coefficients for the Eight Variables (R^2 Values)

Variable	Coefficient
ILN	0.8221
IHT	0.8692
PRA	0.7788
POA	0.7763
AHT	0.8635
SWT	0.6108
SDT	0.7426
ILC	1.4281

If the ilium and the femur were growing at the same rate the coefficient value would be one; but if the growth is slower than the femur, the value is less than one is found. The coefficients were generally similar indicating essentially similar overall growth. Iliac height (IHT) and auricular height (AHT) were nearly equal in their growth rates and were slightly ahead of overall iliac length (ILN). Expansion of the auricular surface is a bit slower than the overall length, overall height and height of the auricular surface indicated in the pre-auricular and post-auricular variables (PRA and POA). Sciatic depth (SDT) expanded slightly faster than did the sciatic width (SWT), and they were slower than the rest of the ilium but not by much. The final variable, iliac crest curvature (ILC) indicates that the iliac crest curvature is increasing at a more rapid rate than the femur length is increasing. This feature may correspond with the increased muscle attachment and force put on this area by the developing upper leg musculature attached to the femur.

To summarize what is reflected in the logrithmic regression coefficients:

a) Overall external growth rates of the ilium is essentially equivalent.

b) Height appears to have a slight growth advantage.

c) The horizontal enlargement of the auricular surface is essentially equal while the surface height is increasing faster than the width.

d) The sciatic notch width is increasing at a slower rate than is the depth, and the notch as a whole is increasing slower than the overall ilium size.

e) The iliac crest curvature is increasing at a rate greater than that of the femur, indicated by a coefficient greater than one.

Inter-Site Correlation

Residual means of the principal component scores were separated by site to evaluate any significant differences between them (Table V). In overall growth (PC1), Leavenworth has the largest ilia while Mobridge II

Table V. Principal Component Means and Standard Deviations for Each of the Four Arikara Sites

PRINCIPAL COMPONENTS	MEAN	STANDARD DEVIATION	
	LEAVENWORTH		
PC1	2.5379	5.8476	
PC2	0.9941	1.5773	
PC3	-0.0737	2.1615	
PC4	-1.0321	1.8326	N= 52
PC5	0.2152	1.4024	
PC6	-0.0345	1.3867	
PC7	0.0105	1.0331	
PC8	-0.3713	0.7325	
	LARSON		
PC1	-0.4523	4.8602	
PC2	-0.4156	1.8630	
PC3	-0.1049	1.8513	
PC4	0.2218	1.5473	N= 188
PC5	-0.0940	1.2053	
PC6	-0.0054	1.0136	
PC7	0.1166	0.8845	
PC8	0.2234	0.8218	
	MOBRIDGE I		
PC1	-0.4081	5.2636	
PC2	0.3754	1.7241	
PC3	0.1381	1.2357	
PC4	0.1475	1.0277	N= 35
PC5	-0.0041	1.2520	
PC6	0.0999	0.7714	
PC7	-0.2144	0.9663	
PC8	-0.2281	0.6107	
	MOBRIDGE II		
PC1	-0.9262	4.8286	
PC2	-0.2282	1.4231	
PC3	0.7450	1.3214	
PC4	0.0359	0.9666	N=18
PC5	0.3936	1.5712	
PC6	-0.3001	1.3303	
PC7	-0.3137	1.3178	
PC8	-0.2627	0.7219	

has the smallest. Component 2 shows the largest factors in Leavenworth and smallest in the Larson site. These along with most of the rest of the components reflect obvious site differences caused by differential age sorting, larger individuals or some other undeterminable influence. By using the entire data set as a whole in any form of specific statistical analysis would result in a good deal of "noise" being produced by these inter-site differences. This "noise" could conceivable reduce the significance of other tests and results unless the sites are separated, or the statistical methods are course enough to withstand the interference.

It is believed that the analysis used in this study should not be greatly influenced by this "noise" since overall shape and size differences in the ilium require large sample sizes. Also in determining sex, the reduced compatibility of size variables should not interfere with accurate separation of sex since sex features would be less controlled by size or age features.

Principal Component Analysis

The previous allometric analysis incorporates growth as indicated by the femur, with ilium shape and size changes. Using principal component analysis, this growth variation is extracted by regressing femur lengths out of the data set and re-calculating correlation tables (Table VI).

Table VI. Eigenvalues for the Principal Components

Principal Components	Eigenvalues
PC1	27.1359
PC2	3.3873
PC3	3.0977
PC4	2.3335
PC5	1.6114
PC6	1.0948
PC7	0.9382
PC8	0.4738

The components then represent portions of the total shape and size variation in the ilium with growth held constant.

Evaluations of each of the components will be made below from results illustrated in Table VII.

Principal Component 1. As is found in all principal component analysis, the first component is the most significant, explaining 67.9% of the variation. Size changes in the overall ilium structure are expressed in this component. There is a slightly larger loading on the iliac length (ILN) than on the iliac height (IHT) suggesting that length increases at a slightly faster rate than does the height. There is also a equally high loading on the post-auricular measurement (POA) almost equivalent to the iliac length (ILN). These similar loadings suggest that the two measurements are essentially equivalent to one another in rates of growth. Lower loadings on the pre-auricular measurement (PRA) and the auricular height (AHT) indicate some low-level relations to

Table VII. Principal Components for Each of the Eight Variables

VARIABLES	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
ILN	0.5712	-0.1490	-0.3277	-0.2750	0.0975	-0.5868	0.3367	-0.0077
IHT	0.4854	0.0377	-0.5914	0.3077	-0.0030	0.4773	-0.2984	-0.0403
PRA	0.2641	-0.2284	0.3497	-0.3217	0.6201	0.0804	-0.5061	0.0725
POA	0.5255	0.1667	0.4820	-0.2521	-0.5737	0.2458	0.0418	0.0937
AHT	0.299[illegible]	0.2741	0.4016	0.7079	0.3127	-0.1624	0.2061	-0.0781
SWT	0.0511	-0.8623	0.1634	0.2755	-0.2156	0.0463	0.0514	-0.3163
SDT	-0.0054	-0.2780	-0.0141	0.1659	0.0409	0.1091	0.2060	0.9160
ILC	-0.0003	-0.0234	0.0046	-0.2407	0.3617	0.5662	0.0715	-0.1980

overall size change. The last three variables have little or no influence in the overall size changes.

Principal Component 2. Representing 8.5% of the total variation, this component has one major loading on the sciatic notch width (SWT). This is the only significant factor variable in the principal components. With less high loadings, sciatic notch depth (SDT), iliac length (ILN) and the pre-auricular measurement (PRA) all contribute some information about the horizontal size variation relationships between these four variables. Negatively correlated post-auricular measurement (POA) and auricular height (AHT) indicate shape variation associated with the sciatic notch. In summation, there are shape changes in the placement of the auricular surface on the ilium with relation to the size of the sciatic notch width and depth.

Principal Component 3. This component accounts for 7.8% of the total variation and indicates shape changes between size of the auricular surface with relation to the overall size of the ilium. The loadings indicate a reciprocating change that, with the enlargement of the overall ilium dimensions, there are subsequent small increases in the auricular shape.

Principal Component 4. Component 4 accounts for 5.8% of the total variation and contains size and shape correlations. The auricular height (AHT) contains the highest loading and corresponds with the iliac height (IHT) and sciatic notch width (SWT) to be negatively correlated to the horizontal size variants iliac length (ILN), pre-auricular measurement (PRA), and the post-auricular measurement (POA). This negative correlation expresses that the vertical expansion of the ilium is greater than the horizontal expansion during growth.

Principal Component 5. This component stresses the auricular surface shape variation. Containing 4.0% of the information, the loadings indicate that with enlargement of the ilium, the auricular surface become slightly narrower and higher as age progresses. This compliments the findings in component 4 that a more vertical formation of shape is made with increase in size. This narrowing is slight and is only really seen metrically.

Principal Component 6. Accounting for 2.7% of the total information, this component somewhat negates the findings in Component 4. The iliac length (ILN) appears to grow slightly faster than the iliac height (IHT). This incongruence may be a result of the size correlation to the iliac crest curvature (ILC) which has a equivalent negatively relative loading to the iliac length. This would indicate that as size increases take place primarily in the height and the iliac crest, an increase in the curvature results with the increase in length.

Principal Component 7. This component appears to deal with three aspects of shape. First, the pre-auricular measurement (PRA) shows a larger increase than the iliac length (ILN). This compliments the findings of component 4 and 5 that the shift of the auricular surface is posteriorly due to enlarging overall size and narrowing of the auricular surface. Secondly, all the vertical measurements seem to increase equivalently as the size and shape of the ilium increase, a factor brought out in Component 1 but including sciatic notch depth (SDT). Finally, the largest loading is found on the iliac crest curvature (ILC) associating with the horizontal changes in shape discussed above. Only 2.3% of the variation is explained by this component.

Principal Component 8. Containing only 1.2% of the total information component 8 reflects the sciatic notch shape again. This time the sciatic notch depth contains the highest loading indicating a much larger increase as subsequent width expansion takes place. Because of the low information percentages and the lack of any other viable information found in the component, this shape variation probably is not too accurate.

Summarizing the principal components, the ilium, enlarges with length growing slightly faster than the height. Shape changes are made in the sciatic notch showing a widening of the notch and subsequent deepening of the curve, repositioning of the auricular surface posteriorly, and a slight narrowing of the auricular surface from infant to adult. The iliac crest curvature increases with the lengthening of the ilium while the sciatic notch shape is somewhat related to the position and shape of the auricular surface.

Graphic analysis was made of each of the principal components versus femur length to determine the extent of growth as an influencing agent. Only the first principal component (PC1) indicated positive growth influences. This graph displays a parabolic shaped curve with a positive skew. It was thought that little or no growth influences would remain as is seen in the graphs and the reason for this non-lineality in the first component is not known. It is possible that this may be a reflection of growth remnants in the component due to its large percentage of the total variation, but this is questionable.

Non-Metric Trait Analysis

This aspect of the study bears on the abilities of the non-metric traits to separate unknown individuals into their appropriate sex groups. As was discussed before, if the non-metric trait discussed by Weaver (1980) does separate the sexes, then by using a large sample of unknown individuals there should be observable separation of the individuals into the two sex groups. The second non-metric trait (the pre-auricular spine) was also analyzed in the same manner to observe its accuracy as a sex criteria and as a "control" in interpreting the results of the auricular surface trait.

The non-metric traits were segregated into femur length increments of 20 millimeters. Femur length increments were used to separate the non-metric observations into age groups to evaluate any differences in ilium variation (Table VIII). Age equivalents for femur lengths were assigned by adjusted dental ages for the Arikara populations following Owsley and Jantz (1983). These ages are adjusted from Moorrees, Fanning and Hunt (1963) values for White Americans. Principal component means for each of the sub-sets were derived and generated (Tables VIII-X).

Table VIII. Age Equivalents to Femur Lengths

FEMUR LENGTH (in mm)	AGE (in years)
70	fetal *
70 - 90	fetal - 0.5
90 - 109	0.5 - 1.0
110 - 129	1.0 - 1.5
130 - 149	1.5 - 2.0
150 - 169	2.0 - 2.5
170 - 189	2.5 - 3.5
190 - 209	3.5 - 4.25
210 - 229	4.25 - 5.25
230 - 249	5.25 - 6.25
250 - 269	6.25 - 7.25
270 - 289	7.25 - 8.5
290 - 309	8.5 - 9.5
310 - 330	9.5 - 10.25

* 78 mm = birth

Source: D. W. Owsley and R. L. Jantz. (1983) Long bone growth variation among Arikara skeletal populations. American Journal of Physical Anthropology (in press).

Table IX. Principal Component Means and Standard Deviations Divided Into Raised and Non-raised Auricular Surface Observations by 20 mm Increments

PRINCIPAL COMPONENTS	NON-RAISED AURICULAR SURFACE N	NON-RAISED AURICULAR SURFACE MEAN	NON-RAISED AURICULAR SURFACE STD	RAISED AURICULAR SURFACE N	RAISED AURICULAR SURFACE MEAN	RAISED AURICULAR SURFACE STD
< 70 mm						
PC1	0	.	.	7	-1.6267	5.8213
PC2		.	.		0.0476	1.7307
PC3		.	.		0.3176	0.8124
PC4		.	.		-0.1290	0.6309
PC5		.	.		0.1903	0.6025
PC6		.	.		0.2107	0.4893
PC7		.	.		0.0700	0.4506
PC8		.	.		0.4197	0.7024
70 - 89 mm						
PC1	21	-2.6350	1.8481	117	-1.9225	2.7833
PC2		-0.1452	1.6046		-0.2662	1.3355
PC3		-0.1270	1.4806		0.1159	1.0407
PC4		0.2548	1.1388		-0.0994	0.8948
PC5		0.3976	0.8325		0.1938	0.7343
PC6		0.1787	0.7206		0.0153	0.5838
PC7		-0.1781	0.7110		0.1421	0.5650
PC8		0.0974	0.5173		0.0131	0.5361
90 - 109 mm						
PC1	4	1.2014	2.5260	14	2.7678	6.1585
PC2		2.0663	0.9407		0.0118	1.5767
PC3		-0.3889	1.0957		0.4468	1.0523
PC4		0.9283	1.1336		-0.5361	1.1788
PC5		-0.1464	1.1870		-0.4843	0.7762
PC6		0.2099	0.5638		0.3415	0.6555
PC7		0.4802	0.5327		0.0271	0.8492
PC8		0.1967	0.2912		-0.0582	0.5280
110 - 129 mm						
PC1	5	4.4395	3.6040	12	4.0200	4.1274
PC2		-0.1376	2.1030		0.2209	1.0566
PC3		-0.6143	3.3062		0.3394	1.9264
PC4		0.2917	1.6482		0.5207	1.7123
PC5		-0.2913	0.8903		0.2394	1.0539
PC6		0.6153	0.6580		-0.1081	1.0656
PC7		-0.3513	0.8849		-0.2680	0.9001
PC8		-0.3297	0.7659		-0.1121	0.5013
130 - 149 mm						
PC1	15	3.4420	3.2699	10	4.7165	3.2718
PC2		0.7095	1.4735		0.7635	1.9681
PC3		-1.1796	1.6614		-0.1529	1.9768
PC4		-0.6260	1.8882		-0.2924	2.3927
PC5		-0.4522	1.0468		-0.4265	0.8021
PC6		-0.5397	1.1567		-0.5255	0.7998
PC7		-0.0610	0.9355		-0.4028	0.9920
PC8		0.0465	0.6597		-0.2258	0.8091

Table IX. (Continued)

PRINCIPAL COMPONENTS	N	NON-RAISED AURICULAR SURFACE MEAN	NON-RAISED AURICULAR SURFACE STD	N	RAISED AURICULAR SURFACE MEAN	RAISED AURICULAR SURFACE STD
150 - 169 mm						
PC1	14	4.4022	5.1931	4	3.0689	2.0545
PC2		1.0381	2.3985		0.7670	1.6228
PC3		0.8667	1.8140		0.2402	1.3526
PC4		0.0193	2.0369		1.3806	1.0257
PC5		-0.9014	1.6918		-0.7022	0.7313
PC6		0.1897	0.9675		-0.0255	0.9369
PC7		-0.5096	0.8940		-0.7982	0.8855
PC8		0.0372	0.5217		-0.2302	0.3566
170 - 189 mm						
PC1	10	5.2878	3.3169	4	6.4049	7.0470
PC2		-0.3899	1.9998		-2.1094	3.3317
PC3		-1.2294	2.3537		0.2169	1.2917
PC4		1.1331	1.1643		-0.1431	1.8511
PC5		-1.2269	1.2379		-1.3376	1.4119
PC6		0.2642	1.2941		0.7333	0.8123
PC7		0.0425	0.8313		-1.3498	1.7181
PC8		-0.2003	0.9141		-0.5813	0.8112
190 - 209 mm						
PC1	12	3.3173	4.6134	2	.	.
PC2		1.0718	1.8084		.	.
PC3		-0.3483	1.7509		.	.
PC4		0.1834	1.7261		.	.
PC5		-0.2446	1.7930		.	.
PC6		-0.4763	1.0128		.	.
PC7		0.0794	1.3959		.	.
PC8		0.0415	0.8940		.	.
210 - 229 mm						
PC1	10	1.7891	5.7819	0	.	.
PC2		0.0066	2.7702		.	.
PC3		-0.4897	2.4568		.	.
PC4		-0.2895	1.9601		.	.
PC5		-0.2486	1.5050		.	.
PC6		-0.8748	1.6110		.	.
PC7		0.5428	1.7797		.	.
PC8		-0.0766	1.2685		.	.
230 - 249 mm						
PC1	6	0.2183	3.7960	3	1.6656	6.9200
PC2		0.6153	3.3369		-2.8857	0.6709
PC3		-1.0952	1.6650		-0.0580	4.3016
PC4		1.2553	1.4973		-0.3305	2.5592
PC5		1.4959	1.7548		0.2575	2.4026
PC6		-1.2728	1.9487		-0.8765	0.8762
PC7		-0.5545	0.5490		-0.2999	0.3928
PC8		-0.0126	0.9113		-0.1048	0.7635

Table X. Principal Component Means and Standard Deviations Divided Into Present and Not Present Spine Observations by 20 mm Increments

PRINCIPAL COMPONENTS	SPINE PRESENT N	SPINE PRESENT MEAN	SPINE PRESENT STD	SPINE NOT PRESENT N	SPINE NOT PRESENT MEAN	SPINE NOT PRESENT STD
<70 mm						
PC1	0	.	.	7	-1.6267	5.8213
PC2		.	.		0.0476	1.7307
PC3		.	.		0.3176	0.8124
PC4		.	.		-0.1290	0.6399
PC5		.	.		0.1963	0.6025
PC6		.	.		0.2107	0.4892
PC7		.	.		0.0700	0.4590
PC8		.	.		0.4197	0.7824
70 - 89 mm						
PC1	7	-1.0952	1.9009	129	-2.0572	2.7143
PC2		0.6588	0.8765		-0.3061	1.3896
PC3		0.6526	0.8629		0.0542	1.1287
PC4		0.2813	0.7107		-0.0524	0.9512
PC5		0.3906	1.0051		0.2171	0.7437
PC6		0.2673	0.1910		0.0299	0.6201
PC7		-0.1365	0.2442		0.1162	0.6077
PC8		0.1414	0.2442		0.0249	0.5864
90 - 109 mm						
PC1	3	6.2754	9.7777	15	1.6399	4.4310
PC2		1.6140	0.6114		0.2392	1.7457
PC3		0.0550	0.7551		0.3023	1.1012
PC4		1.3402	1.0702		-0.5209	1.1226
PC5		0.7061	0.9997		-0.3498	0.8493
PC6		0.4046	0.9352		0.2938	0.5864
PC7		0.9521	1.1288		-0.0371	0.6476
PC8		-0.0577	0.3243		0.0100	0.5250
110 - 129 mm						
PC1	1	.	.	15	4.1419	4.0554
PC2		.	.		0.0050	1.4327
PC3		.	.		0.4720	2.3803
PC4		.	.		0.1359	1.6604
PC5		.	.		-0.0243	1.0329
PC6		.	.		-0.0243	0.9957
PC7		.	.		-0.2953	0.8989
PC8		.	.		-0.2273	0.5930
130 - 149 mm						
PC1	11	4.3878	3.4648	14	3.6092	3.1865
PC2		0.2732	1.4287		1.0910	1.7703
PC3		-0.7874	1.9302		-0.7544	1.8160
PC4		-1.0361	2.0749		-0.0655	2.0239
PC5		-0.3652	1.0637		-0.5022	0.8641
PC6		-0.6319	1.2185		-0.4571	0.8529
PC7		-0.3265	1.0600		-0.0965	0.8880
PC8		0.1334	0.6812		-0.2163	0.7357

Table X. (Continued)

PRINCIPAL COMPONENTS	SPINE PRESENT N	SPINE PRESENT MEAN	SPINE PRESENT STD	SPINE NOT PRESENT N	SPINE NOT PRESENT MEAN	SPINE NOT PRESENT STD
150 - 169 mm						
PC1	16	4.1645	5.5834	2	.	.
PC2		1.1716	2.2662		.	.
PC3		1.0087	1.6798		.	.
PC4		0.1120	1.9369		.	.
PC5		-0.8177	1.5803		.	.
PC6		0.1778	0.9598		.	.
PC7		-0.7111	0.8254		.	.
PC8		-0.0173	0.5246		.	.
170 - 189 mm						
PC1	8	6.1263	3.1187	6	4.9146	5.9740
PC2		-0.2012	2.0084		-1.7379	2.8591
PC3		-0.1179	1.7217		-1.7472	2.4896
PC4		1.3613	1.0263		-0.0218	1.6249
PC5		-1.6454	1.0522		-0.7426	1.3612
PC6		0.4299	1.3879		0.3559	0.9141
PC7		0.0949	0.5309		-0.9556	1.7239
PC8		0.1699	0.5916		-0.9480	0.7969
190 - 209 mm						
PC1	13	3.0740	4.5032	1	.	.
PC2		1.0350	1.7364		.	.
PC3		-0.4960	1.7590		.	.
PC4		0.2354	1.6632		.	.
PC5		-0.2792	1.7212		.	.
PC6		-0.4692	0.9700		.	.
PC7		-0.0460	1.4110		.	.
PC8		0.0747	0.8642		.	.
210 - 229 mm						
PC1	10	1.7891	5.7819	0	.	.
PC2		0.0067	2.7702		.	.
PC3		-0.4898	2.4569		.	.
PC4		-0.2895	1.9601		.	.
PC5		-0.2487	1.5050		.	.
PC6		-0.8748	1.6110		.	.
PC7		0.5428	1.7797		.	.
PC8		-0.0767	1.2685		.	.

In the results the most apparent problem was in sub-set sample sizes. In the early ages (newborns) there were vast sample size discrepancies to the order of 5.5 times in the auricular surface trait (APO), and 18 times in the pre-auricular spine trait (ASP). These results alone question the accuracy of these traits as sex determining criteria. If infanticide was being practiced by the Arikara (of which there is no record) the possibility of a 2:1 ratio might be possible, but not a 6:1 ratio. This biasing towards one trait then begins to decrease with increasing age and is subsequently switched to the opposite trait in the older ages in both observations.

The large sample size divergence in the newborn sub-set is opposite what Weaver found (Table III, p. 6). In the present sample the largest quantity is found in the raised category of the auricular surface trait while in Weaver's sample the largest sample size is found in the non-raised category. It was first thought that this disagreement in higher weighted categories between studies was due to the inability of the non-metric trait to be reproduced without personal instruction. And in fact this may be true, but with the pre-auricular spine trait also displaying unrealisticly disproportionate numbers like the auricular surface trait, may indicate real morphological age changes and not problems in the area of observer error.

When looking at the data, almost all the individuals at birth have raised non-spined traits, but as age progresses to 130mm femur length (1.5 years), the averages of the traits begin to approach equal proportions. Then as the femur lengths increase again, although the sample sizes have diminished, the non-raised and spined traits are more prevalent. This change in the data is simply a progressive change of traits due to age. Thus, when newborn, the traits are raised, non-spinous but as age increases, non-raised and spinous traits become more frequent. If there is any sex relatedness to these apparently age-related traits, they are minor and hidden deep within the age related features.

The most interesting finding concerning the non-metric traits was the significant relationships between raised auricular surface-no spine and non-raised auricular surface-present spine (Table XI). The exact relationships of these non-metric traits is not clear but it appears to have something to do with the integration of auricular surface shape and sciatic notch shape and size. The spinous process is generally is associated with narrower sciatic notches and larger, non-raised auricular surfaces while the opposite is found in non-spinous ilia. Again both these traits are age related features, but their correlation is interesting.

The principal component score means for each of the sub-sets were analyzed and no significant variables were found. This was not surprising since the results of the non-metric tests showed no other significant aspects than that of age changes which was to be regressed from the components. One interesting feature to be noted is the reflection of the parabolic scattering of component one's (PC1) data in the progressing sub-set means.

Table XI. Relationship of Auricular Surface Observations and Spine Observations

ASP / FREQUENCY / PERCENT / ROW PCT / COL PCT	APO: NON RAISED	RAISED	TOTAL
NOT PRESENT	33	164	197
	11.26	55.97	67.24
	16.75	83.25	
	28.21	93.18	
PRESENT	84	12	96
	28.67	4.10	32.76
	87.50	12.50	
	71.79	6.82	
TOTAL	117	176	293
	39.93	60.07	100.00

$\chi^2 = 134.69$

$\phi = 0.678$

V. CONCLUSIONS

The analytic objectives of this study can be divided into three main phases: 1) allometry with respect to femur length as a growth rate age indicator, 2) material changes due to growth correlated to morphological changes in the ilium, and 3) non-metric morphology of the ilium and their relationships to age and sex. But how do all of these features interrelate? It is evident from the results that age changes in the ilium are a complex conglomeration of correlated factors. Unlike the long bones, where growth is primarily two dimensional, the ilium grows in three dimensions. In the long bones, growth is mainly superior-inferior, but in the ilium anterior-posterior growth is as great, if not greater than superior-inferior change. The auricular surface and the sciatic notch must also change to remain morphologically functional.

Anterior-posterior lengthening of the iliac crest and corpus takes place to accommodate the enlarging leg musculature associated with increasing femur length. Associated with this leg musculature is the constantly reforming of the superior-inferior design to allow correct placement of the fulcrum position for optimum lateral leg support. The increasing lateral curvature of the iliac crest also aids in the vital fulcrum positioning.

As the overall size and thickness increases, the position and angle of the sacro-iliac articulation also changes. The entire articulation moves posteriorly along with overall expansion and the auricular surface area becomes greater assisting pelvic body support. The auricular surface angle is a reflection of the position of the sacrum in the pelvic girdle and the degree of kyphosis present in the spine. Variations in this spinal angle are also reflected in the shape of the sciatic notch width and depth. A more anterior, vertical sacro-iliac articulation results in a narrower, deeper notch, while a posteriorly positioned, more angulated, sacrum will result in a more shallow, wide sciatic notch. These differences of course are either incipient sexual differences in the ilium seen in their formative stages or the formation of individual variation.

In general, this analysis reflects the changes and variation which takes place in the ilium during normal growth. Sexual differences cannot be identified by these methods because of the inabilities of the non-metric sex distinguishing traits and because the sample's sexes are unknown. Nevertheless, statistical analysis of this sort would be extremely helpful in possibly deciphering some of the sexual differences in a more concise manner than Boucher's, Wèaver's or Reynold's indices do. The use of indices only begins to touch upon differences that logrithmic correlation coefficients and principal components can separate. It is only in Reynold's studies that growth related features are measured and as is done in the present study, a range of ages and large sample is used. Reynold's studies however, used known individuals which he was able to segregate by sex, and he used measurements from radiographs rather than from the mascerated bony pelvis eliminating comparison with skeletal samples.

This study has aided the understanding of growth and age changes of the bony ilium through statistical analysis. It is evident that particular areas of the ilium correspond directly with others in their processes of change, while other areas are less influenced by these changes. Interestingly, the areas which were thought to be most sexually divergent, namely the non-metric traits and sciatic notch, proved to be age related features. Therefore, depending on the stage of development, one expression of a trait is found early in growth and then shifts to the other expression in later growth. What sex differences may exist are obscured by the age changes.

It was found that controlling age by segregating femur length, age related variation was not completely eliminated through regression. This was graphically displayed by the parabolic curve in Principal Component 1 and although not as strong, probably in the other components as well. Possibly if all age related differences were eliminated, some significant sex differences may have appeared and the principal components partial scores may have been generated. Heterogeneous regression lines between femur lengths and principal components or non-linear relationships of ilium to femur lengths may have caused this lack of segregating age variation. A possible amend to these problems would be the use of non-linear quadratic equations rather than linear regression equations to more closely match ilium to femur length data before calculating principal components.

Although this study indicates that sex differences are absent from the non-metric and metric traits, further statistical analysis done in the same manner as this study on known samples might be helpful in searching for sex differences in sub-adults. By using a known sample, the variances might be lowered on the principal component and logrithmic means to significant levels. Re-analysis of age related and sexual differences between the non-metric traits could be examined and might produce some information that has been overlooked in this study. Auricular surface angle, its position and relationship to the sciatic notch shape, and iliac crest curvature changes are all topics which still deserve closer attention. With the new information resulting from increased study of the subadult ilia, new methods to understand growth changes, and successful sex determination in the ilium will benefit not only growth studies but forensic and paleodemographic analysis as well.

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VITA

David R. Hunt was born in Rochester, Minnesota on May 15, 1958. He attended elementary school in Washington, Illinois and graduated from Washington Community High School with Honors in 1976. He entered the University of Illinois in the fall of 1976 and in the summer of 1980 received double major Bachelor of Arts degrees with Honors in both Anthropology and Classics. During his undergraduate career he participated in archeological fieldwork in Illinois (Cahokia Mounds, Two Fork Creek site, Lake Shelbyville salvage work and Orendorf site), Louisiana (Pargoud Landing site) and Sicily, Italy (the Morgantia site). He also worked as a metals conservationist and researcher for the World Heritage Museum, University of Illinois, Urbana-Champaign, primarily working with French Bronze Age artifacts. He also participated in physical anthropology fieldwork at the Field Museum, Chicago, Illinois.

His interests now center on skeletal biology, human variation and classical archeology. He is a member of the American Association of Physical Anthropologists, the American Association Field Archeologists and the Archeological Institute of America. His secondary interests are vocal and instrumental music, antiques and woodworking.

During his life he has been employed in city road repair, as a Boy Scout counselor, machinist, and metals conservationist for the World Heritage Museum. His future goals are to remain in the study of human biology, variation and evolution.